Spatial distribution of fine roots of larch and ash in the mixed plantation stand

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Abstract: The spatial distribution of standing fine roots in tree rows of different species in a 12-year-old mixed stand of ash (*Fraxinus mandshurica* Rupr.) and larch (*Larix olgensis* Henry) was studied by soil core sampling in early spring, 2001. It is found that ash and larch differ greatly in their belowground biomass distribution. Ash has much higher fine root biomass density in the soil than larch at stand level (with the max value of 4442.3 vs. 2234.9 g·m^{-3}). Both tree species deployed more fine roots in their neighboring zone, suggesting a less intensive competition between roots of the two species. Both fine root biomass density and root length density of ash in the zone between larch tree rows are greater than that of larch in zone between ash tree rows, indicating that ash is more powerful than larch in belowground competition. The spatial distribution feature of roots favors the growth of ash in the mixed stand.
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Introduction

Root system is one of the most important components of a forest ecosystem, and it plays a vital role in the uptake of water and nutrients from soil, anchorage, and carbohydrates and nutrients storage. The growth and turnover of roots have a dramatic influence on the allocation of net primary productivity as well as nutrient recycling (Fahey. and Hughes 1994; Gholhz *et al.* 1986; Gerier *et al.* 1981). Root system is complex in that it is composed of roots differed in diameter, i.e. different root class as root stock, lateral root, coarse root, fine root, and root hair. Fine root is the most active and sensitive component in the root system (Nadelhoffer 2000; Henrick *et al.* 1993; Jackson and Caldwell 1989), and responses to environmental variation with great plasticity (Eissenstat, *et al.* 2000; Mou *et al.* 1997). The growth and turnover of fine roots cost as large as 50%-70% of the total net primary production of plant ecosystem, which is a key factor for aboveground biomass accumulation and global carbon recycling. Different plant species differ in their plasticity to the environmental variations (Einsmann *et al.* 1999; Mou *et al.* 1997; Grime *et al.* 1991). Some species with high plasticity gain advantage and become more powerful competitors.

Manchurian ash (*Fraxinus mandshurica*) and Changbai Larch (*Larix olgensis*) are two important commercial timber tree species, and their mixed stands are usually more productive than their respective monoculture stands (Chen *et al.* 1997). The ash species always benefits from the association with larch trees. Many researches have been done to unveil the mechanism lying bellow, and most of which focused on the aboveground interactions (Wang *et al.* 1997), inter-specific nutrition relationship (Zhang *et al.* 1997), however, less has been done on the mechanism with the belowground component, i.e., the roots. If ash gains benefit from underground association with larch, certain responses of roots of ash to this association are expected, and the underground structure should favor the resources acquisition of ash. We conducted a field soil core sampling to test this hypothesis.

Site description

The study was conducted in a 12-year-old mixture stand of ash and larch in Jianlagou Research Forest (45°16' N, 127°43' E) of Northeast Forestry University, Heilongjiang Province, China. The study area is located at the northeast edge of Changbai Mountains, and characterized by continental climate, secondary growth forest as typical vegetation. The annual mean precipitation is 723.8 mm, distributing unevenly with more than 70% concentrating in summer. Mean annual temperature is 2.8°C. Frost-free period is 120-140 days. The soil is Dark-brown Forest Soil, a well-developed soil under natural forest vegetation, with high organic matter content, well drainage and aeration. The stand was established in the clear-cut strips across the contour line within the secondary forest. In the mixed stand, three rows of larch, and three rows of ash were planted alternatively with the initial spacing of 1.5 m×1.5 m. The features of the stand are listed in Table 1.

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Table 1. Features of the mixed stand of ash and larch

Species	Stand density (stem/hm^{-2})	D.B.H /cm	Height /m
Ash	1746	5.73	13.1
Larch	1783	8.15	17.1

Data collection

Samples were taken using a soil core (6.5 cm in diameter) in early spring, 2001, to a depth of 30 cm. Sampling positions were laid out as shown in Fig.1. The sampling zone between larch, larch and ash, ash and ash are expressed as LL zone, LA zone and AA zone, respectively. Thirty samples were taken along the central line between the tree rows. Totally 270 soil cores were sampled. Each soil core was separated into 3 sections, i.e., 0-10 cm, 10-20 cm, and 20-30 cm. The soil cores were stored in frozen before treatment in the lab.

The soil cores were thawed in cold water. The soil and woody debris were removed. The living roots were classified into three categories, fine root (≤2 mm), coarse root (2-5 mm), and lateral root (>5 mm). Root architecture, color, elasticity were used to distinguish roots of different tree species, dead and living roots. The length of all living fine roots in each sample was estimated using the grid method (Böhm 1979). The roots were dried at 65°C to constant mass and weighed.

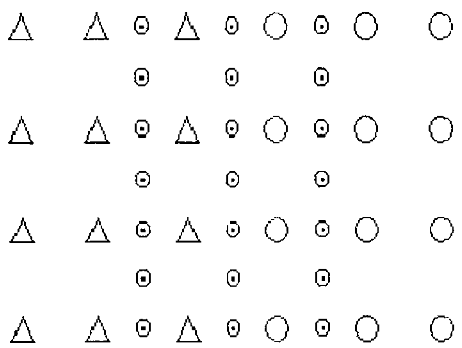

Fig.1 Representative layout of the sampling positions

Δ-larch O-ash ⦿ -sampling position.

Results

At stand level, the root biomass density (RBD) in the sampled depth differed significantly between species The total RBD of roots in different diameter classes of ash are 0.70, 1.68 and 6.38 times larger than that of larch in LL, LA and AA zone, respectively (Table 2).

The fine roots (≤2 cm) are the major component of the roots in all three zones, accounting for 79.5%, 66.0%, 75.5% of the total root biomass density of ash, and 70.4%, 80.0%, 100% of that of larch in LL, LA, AA zone, respectively (Table 2).

Table 2. Standing biomass of ash and larch roots in different zones /g m^{-3}

Species	Root class /cm	LL zone	LA zone	AA zone
Ash	≤2	1767.2	2346.0	3353.6
	2-5	370.4	998.8	749.8
	>5	84.0	209.1	338.9
	Total	2221.6	3553.9	4442.3
Larch	≤2	2234.9	1713.9	696.6
	2-5	361.0	175.5	0.0
	>5	578.9	226.4	0.0
	Total	3174.7	2115.7	696.6

Remark: Data of the three soil core sections were pooled and averaged for each sampling position.

The pooled fine root biomass density (FRBD) in 0-30 cm soil layer (ash plus larch averaged in three soil layers) increases slightly from LL zone to AA zone, but not significant (Table 3). In contrast, the total fine root length density (RLD) increases dramatically, with the lowest value in LL zone (7.83 cm·cm^{-3}) and the highest value in AA zone (14.48 cm·cm^{-3}) (Table 4).

Table 3. Fine root biomass density of ash and larch in different zones /g· m^{-3}

Species	Soil depth /cm	LL zone	LA zone	AA zone
Ash	0-10	2913.8	3431.2	5560.9
	10-20	1576.3	2450.6	3325.2
	20-30	811.5	1156.2	1174.7
	mean	1767.2	2346.0	3353.6
Larch	0-10	3500.9	819.7	835.9
	10-20	1834.4	761.1	813.9
	20-30	1369.4	133.1	440.0
	mean	2234.9	1713.9	696.6
Ash plus larch	0-30	4002.1	4059.9	4050.2

Table 4. Fine root length densities of ash and larch in different zones (cm/cm^{3})

Species	Soil depth /cm	LL zone	LA zone	AA zone
Ash	0-10	10.05	14.66	23.48
	10-20	5.44	10.47	14.04
	20-30	2.80	4.94	4.96
	mean	6.10	10.02	14.09
Larch	0-10	2.71	1.54	0.38
	10-20	1.42	1.43	0.37
	20-30	1.06	0.25	0.20
	mean	1.73	1.07	0.32
Ash plus larch	0-30	7.83	11.10	14.48

In both species, the fine roots concentrated in the soil between the rows of their respective species (LL zone for larch, AA zone for ash), and were distributed less in LA zone, and in zones between the other species (Table 3).

In LA zone, the FRBD of both species are greater than half FRBD of each species in their respective zone (2 346.0 vs. 1 676.8 g m^{-3} for ash, 1 713.90 vs. 1 117.5

$g \cdot m^{-3}$ for larch) (See Table 3), and also the RLD (Table 4).

Significantly higher FRBD and RLD of ash are found in LL zone than that of larch found in AA zone (1 767.2 vs. 696.6 $g \cdot m^{-3}$, 6.10 vs. 0.32, Table 3, Table 4).

Significant difference is detected in RLD between the two species in all the three zones. The mean RLD of ash in LL, LA, AA zone is 3.5, 9.4, and 44.0 times larger than that of larch, respectively (Table 4).

Most of the fine roots of both species concentrated in the upmost soil layer, and the FRBD and RLD decreased downward. Significant difference in FRBD and RLD is found among different soil layers in all three zones for both species (Table 3, Table 4). The FRBD of ash in the 0-10 cm soil layer accounts for 55.0%, 48.8%, and 55.3% of total FRBD in three layers as a whole, in the three sampled zones, respectively (Table 3, Table 4). For larch, the ratio is 52.2%, 47.8%, and 40.0%. Ash tends to allocate more fine roots in the 0-10 cm soil layer than does Larch (Table 3).

Discussion

Foliage and roots are the main resources foraging organs of plants. The competitive outcome among different individuals in a community will be determined by the competitive ability of both aboveground and belowground parts of different species. In our research stand, ash is an inferior tree species in the mixture, and the aboveground size of ash trees is smaller comparing to larch (Table 1). This suggests that the light environment in the stand might favor larch rather than ash. Question stems from this fact, why yield of ash is usually improved when growing in mixture with larch? The answer is expected to be with the belowground parts, the roots.

It is found that larch has much lower RBD comparing to that of ash. The ash trees might most probably dominate the belowground competition. Even in the LL zone, the RBD of ash accounts for more than 40% of the total in the soil depth of 0-30 cm (Table 2).

The fine roots are the major component among the three root classes in both tree species. Since fine roots are the major resources foraging component, their spatial distribution is more descriptive to the interspecific competition. In LL zone and AA zone, the maximum values of FRBD are found for larch and ash, respectively. These fine roots can be attributed to the two rows of the neighboring trees of the same species. In LA zone, the fine roots of each species are from one row of trees of ash and larch. It is logical that we compare the FRBD of each species in LA zone to half the value of FRBD of each species in LL zone and AA zone if the spatial distribution of fine roots is symmetric (Silander & Pacala 1990). The FRBD of ash and larch in LA zone is greater than half of that in their respective zone. This may be explained as the result of less intensive competition between roots of the two species in LA zone since it is well known that coniferous and broadleaved tree species differ in their nutrition utilization regime (Pielou 1988).

In larch zone (LL), the FRBD of ash is higher than the half of FRBD in ash zone (AA) though it is not significant, but much less FRBD of larch is found in ash zone than in Larch zone. The ratio of mean FRBD of ash and larch in the three zones from LL to AA is 1: 1.32: 1.90, and 3.20: 2.46: 1, respectively (Table 3). The fine roots of ash are more evenly distributed in the three zones than that of larch. Larch concentrates more of its fine roots in LL zone than ash in AA zone. This suggests ash is a more powerful competitor of belowground resource.

The mean RLD of larch in LL zone is very much less than that of larch in AA zone (6.1 vs. 0.32 $cm \cdot cm^{-3}$), suggesting that the soil bulk is less exploited by larch in LL zone. Ash made use of the bulk soil in larch zone being less exploited by larch fine roots, because it deployed comparatively more of its fine roots into larch zone than larch did to ash zone. This reduced the difference of the total RLD (ash plus larch) between LL zone and AA zone (7.83 vs. 14.48 $cm \cdot cm^{-3}$).

Roots of different tree species differ in their nutrients foraging behavior. They may enhance nutrient uptaking rate by their plasticity in morphology, demography, physiology as well as mycorhiza association (Hutchings *et al.* 2000; Jackson & Caldwell 1996; Smith & Read 1997). Here we present only the standing biomass and root length of fine root, which may to some extent explain the belowground interspecific relationship between larch and ash. More work should be done to completely understand the belowground interactions that benefit the growth of ash in the mixed stand.

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